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Comment: Efficiency of ITQs in the Presence of Production Externalities

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Introduction

Professor Danielsson (2000) argues that congestion externalities are solved if individual transferable quotas (ITQs) are introduced. This is in direct contrast to my own research (Boyce 1992; Corollary 1, p. 399). Danielsson raises an interesting question about how congestion externalities should be modeled. However, I argue that my own result is fundamentally correct, based on the assumptions I made. Furthermore, my paper defines congestion externalities in a manner that is consistent with the literature, while Danielsson does not. In addition, the manner in which Danielsson specifies congestion externalities is indistinguishable from a pecuniary externality—thus, it is hardly surprising that he finds that ITQs simultaneously solve both the congestion and common property externality problems.

On The Form of Congestion Externalities in a Fishery

When I think of congestion externalities, I usually have in mind something like that which occurs in the salmon fishery in Bristol Bay, Alaska.[1] In the Dillingham section of that fishery, the Alaska Department of Fish and Game prohibits fishing further out than one mile from the mouth of the Naknek River. The fishing openings typically occur when the tide is running in, since the fish have evolved to take advantage of this push up the river. This means that the fishermen, who use driftnets, line up on the imaginary line one mile out. As the bay is not wide enough to fit all of the fishermen simultaneously on the line, some fishermen wait in a queue while others fish, since to set one's net behind the front line is less productive. However, since the tide is running in, a fisherman who sets his net on the line is immediately pushed off the line by the tide. I once observed a six-meter long pole with a "Y" at one end on a boat I visited. The captain told me that the pole was used to push the net of the fisherman on the front line down into the water as the captain passed his boat over the front line fisherman's net with his propeller. The amount of time a boat spends on the front line is roughly equivalent to the amount of time it takes before the tide washes the boat in enough so that another boat can fit in front of him. This is wasteful, since it is optimal to not have idle boats waiting to jump into the queue,

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I thank Jeff Church and Ken McKenzie for helpful discussions. I also thank the editor, James L. Anderson, and the associate editor, Keith R. Criddle, for the opportunity to make this reply.
[1] ITQs are not used in this fishery. The example is provided only to illustrate the nature of the congestion externality problem.

and since a fisherman does not get to keep his net in the water until it is full.

The essential feature of this queuing example is that the length of the queue depends upon how many boats are on the water (and on technical features, such as how fast the tide is moving and how wide the bay is). The number of boats on the water is an *input* measure, not an *output* measure. It was in terms of inputs that I modeled congestion externalities. This is in keeping with the literature.[2] However, Danielsson models congestion in terms of outputs, not inputs. His only defense of this is to say "it seems likely that production externalities, in the form of crowding, can be modeled realistically by assuming that it is the sum of the activities of other firms that matters" (2000, pp. 37–38). In equation (1), Danielsson makes it clear that the "activities of other firms" refers to the other firm's output.

Let me provide another example that shows why it is that inputs, not outputs, are the correct way to model congestion externalities. Consider the case of road congestion. The way in which economists have specified road congestion is to say that as the number of cars on the road increases (*i.e.*, as the inputs increase), the average speed (*i.e.*, the output) of each car decreases.[3] In Danielsson's specification, where it is the outputs that create the congestion costs, one would conclude that the speed of car i decreases as the speed of the other cars increases.

If inputs are the correct measure, one can specify the production function for fisherman i as:

$$h_i = f(x_i, x_{-i}), \tag{1}$$

where $x_{-i} \equiv \sum_{j \neq i}^{N} x_j$. Here, the congestion externality occurs because the production function is assumed to have the property that $f_2 < 0$.[4] In addition, $f_1 > 0$ and $f_{11} < 0$ is also assumed. If this is the case, then the cost of producing output equal to h_i equals:

$$c_i \equiv \min_x wx_i \text{ subject to } f(x_i, x_{-i}) \geq h_i. \tag{2}$$

Let μ be the Lagrange multiplier corresponding to the binding harvest constraint. This problem has necessary conditions:

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[2] Smith (1968, p. 413) defines a "crowding externality" to occur when an individual fisherman's costs (which he does not obtain from a production function) are increasing at the aggregate capital level. This is an input definition, not an output definition. Smith (1969, p. 181) uses a similar definition, "crowding externalities occur if the fish population is sufficiently concentrated to cause vessel congestion over the fishing grounds and, thus, increased vessel operating costs for any given catch." Brown (1974, p. 165) also defines congestion externalities as arising from inputs "defined in terms of boats in the case of the fishery, number and location of wells in the instance of groundwater, and hunters in the case of waterfowl." Clark (1980, p. 1126) defines an externality in terms of inputs; the cost to the ith fisherman increases as the "effort" of the other j fisherman increases. Karpoff (1987, pp. 184–85) defines the crowding externality in terms of an individual production function that is decreasing in the number of vessels. See also McConnell (1977).

[3] See Walters (1987) for a review of congestion externalities in the non-fisheries literature. Briefly, Dupuit (1844) was the first to discuss congestion. Pigou (1912) interpreted the waste due to congestion in roads as a metaphor for perfect competition, thus concluding that perfect competition is wasteful. Knight (1924) was the first to point out that private ownership of roads would not result in the congestion externality problem identified by Pigou, since private owners would have an incentive to charge users a competitive price for access to the road. Gordon (1954) was essentially applying Knight's road congestion model to a fishery.

Danielsson's claim is, in spirit, similar to Knight's. However, the difference between the simple road congestion problem and congestion in a fishery is that in a fishery more variables are endogenous. In the simplest road congestion problem (homogeneous cars each traveling the same distance), the only issue is the number of cars on the road. In a fishery, the endogenous variables include the number of fishermen, the amount of inputs used by each fisherman, and the length of the season. If there were two types of vehicles, say passenger cars and semi-trucks, a single price is not sufficient to resolve the congestion externalities problem.

[4] Throughout, I use the notation that $f_1 \equiv \partial f(x_i, x_{-i})/\partial x_i$, and $f_2 \equiv \partial f(x_i, x_{-i})/\partial x_{-i}$, where the subscript refers to the argument order.

$$w - \mu f_1(x_i, x_{-i}) = 0, \text{ and } h_i - f(x_i, x_{-i}) = 0. \tag{3}$$

The interpretation of μ is that it is the marginal cost of the constraint that the harvest equals h_i. This model has three parameters: h_i, w, and x_{-i}. Thus, the solution to equation (2) in x_i^* and μ^* are each functions of h_i, w, and x_{-i}, and the cost function $c_i^*(h_i, x_{-i}, w) = wx_i^*(h_i, x_{-i}, w)$ has the following comparative statics properties:[5]

$$\frac{\partial c_i}{\partial h_i} = \frac{w}{f_1} > 0, \quad \frac{\partial c_i}{\partial w} = x_i^* > 0, \text{ and } \frac{\partial c_i}{\partial x_{-i}} = \frac{-wf_2}{f_1} > 0. \tag{4}$$

Thus, the cost function $c_i^*(h_i, x_{-i}, w)$ is increasing in each of its arguments. Notice, however, that its arguments include the firm's own output, but not the output of other firms. The other firms affect firm *i*'s costs by the quantity of their inputs x_{-i}, not by the quantity of their outputs. One might think that this can be inverted using a duality relationship to obtain a cost function that contains the output of the other fishermen as an argument. I show in the next section that the form of this cost function cannot be as Danielsson specifies his cost function.

To summarize, the production relationship I specified yields a cost function that has observable properties, all derived from the underlying production function.[6] Danielsson has not derived the production function relationship that generates the cost function he used. Thus, we have no check on whether or not his definition of a production externality makes sense.

The Efficiency of ITQs in the Presence of Congestion Externalities

The Efficiency of ITQs When the Congestion Externality is of the Form $h_i = f(x_i, x_{-i})$

I now show, using a simplified version (which ignores the stock externalities) of the model from my original paper (1992, pp. 393–6), that the result I obtained in that paper is correct: ITQs do not solve the congestion externality problem.[7] In particular, I shall assume that there are *three* endogenous variables: the input used by each identical fisherman, x_i; the number of fishermen, N; and the length of time it takes these fishermen to harvest the entire season quota, T.[8] Danielsson, in contrast, assumes that only the harvest levels of each fisherman are endogenous.[9] Most fisheries economists seem to believe that there are multiple margins at which rents are dissi-

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[5] It can also be shown that the marginal cost is affected similarly:

$$\frac{\partial \mu}{\partial h_i} = \frac{\mu f_{11}}{-f_1^2} > 0, \quad \frac{\partial \mu}{\partial w} = \frac{1}{f_1} > 0, \text{ and } \frac{\partial \mu}{\partial x_{-i}} = \mu \frac{(f_{11} f_2 - f_{12} f_1)}{f_1^2} > 0 \text{ (when } f_{12} \leq 0\text{)}.$$

[6] This cost function is consistent with the literature. See note 2, supra.

[7] The model used in my (1992) paper is more complicated because I was attempting to simultaneously analyze congestion and stock externalities.

[8] These are the same three variables that were endogenous in my original paper. It is possible to derive the same qualitative results for a model in which the season length is not included. In that case, harvest, *h*, is the season harvest, where in the specification in the text, the season harvest by fisherman, *i*, is Th_i. The issue, however, is that more than one variable is endogenous in a fishery. If only the number of fishermen were the issue, then ITQs would solve both the congestion and common property externalities. However, when more than one variable is endogenous, this is not the case.

[9] I show below that this is not what causes the difference between our results. However, whenever there is only one cause of both the common property and congestion externalities, only one instrument is needed to solve both problems.

pated (*e.g.*, Wilen 1979; Townsend 1990). Thus, I stand behind my assumption that there are multiple endogenous variables.

Let the single season profit function for an individual fisherman be specified as:

$$\pi_i = T[pf(x_i, x_{-i}) - wx_i] - k_i, \tag{5}$$

where p is the exogenously determined output price, and k_i is a fixed-but-avoidable cost of entry. In what follows, I shall assume that all fishermen are identical, so $k_i = k$ and $f_i = f$ for all i.

The social planner's problem is to choose T, $\{x_1, x_2, \ldots, x_N\}$, and N to maximize:

$$V = \sum_{j=1}^{N} \pi_j . \tag{6}$$

subject to an aggregate harvest constraint:

$$Q \geq T\sum_{j=1}^{N} h_j . \tag{7}$$

where Q is the total allowable catch for the season, and a constraint on the season length that:

$$T \leq \bar{T}. \tag{8}$$

Let the Lagrange multipliers be λ and τ, respectively. The first-order necessary conditions include:

$$\begin{aligned} (p-\lambda)[f_1 + (N-1)f_2] &= w, \\ T\{(p-\lambda)[f + (N-1)f_2 x] - wx\} &= k, \\ N[(p-\lambda)f - wx] = \tau &\geq 0. \end{aligned} \tag{9}$$

In the event that $T < \bar{T}$, $\tau = 0$. But this implies $T(p - \lambda)(N - 1)f_2 x = k$, which cannot hold since $f_2 < 0$. Therefore, the social optimum is characterized by the following:

$$T = \bar{T},\ TNf = Q, \text{ and } T\left(\frac{f - f_1 x}{f_1 + (N-1)f_2 x}\right) = \frac{k}{w} \quad \text{Social Optimum.} \tag{10}$$

Notice that the social planner's solution explicitly accounts for the congestion externality in that the f_2 term appears in equation (10).

Under ITQs, suppose each fisherman is given an initial quota of $q_0 = Q/N_0$, where N_0 is the initial number of fishermen (say under open access). Let z_i be the quantity of quotas fisherman i purchases during the season, and let m be the (annual rental) quota price, which each fisherman takes as exogenous. Then, an individual fisherman chooses x_i, z_i, and T_i to maximize:

$$\pi_i = T_i[pf(x_i, x_{-i}) - wx_i] - mz_i - k_i \tag{11}$$

subject to the season length constraint in equation (8) and the constraint that he harvests no more than the quantity of quotas he owns:

$$q_0 + z_i \geq T_i f_i(x_i, x_{-i}). \tag{12}$$

Assume Nash behavior by all individuals and that each individual acts as a price-taker in the input, output, and quota markets. Let τ_i and λ_i be the corresponding Lagrange multipliers. The necessary conditions include:

$$\begin{aligned} \lambda_i &= m, \\ (p - m)f_1 &= w, \\ (p - m)f - wx_i &= \tau_i \geq 0. \end{aligned} \tag{13}$$

In addition, fishermen must earn profits at least equal to the profits they could obtain if they simply sold their quotas. In light of equation (12), and assuming perfect mobility of resources, this implies:

$$T[(p - m)f(x_i, x_{-i}) - wx_i] - k_i = 0. \tag{14}$$

These may be rearranged to show that the symmetric ITQ equilibrium includes:

$$T = T, \; TNf = Q, \text{ and } T\left(\frac{f - f_1 x}{f_1}\right) = \frac{k}{w} \quad \text{ITQ Equilibrium} \tag{15}$$

While ITQs do utilize the full season length, which is socially optimal, they do not allocate effort optimally, since the third expression differs from the corresponding expression in equation (10). In particular, the difference is that under ITQs, the congestion externality [the f_2 term in the third equation of (10)] does not appear in equation (15). Therefore, ITQs do not solve the congestion externality problem when the externality problem is cast in the manner assumed in this model. Thus, my original result is affirmed (Boyce 1992).

It is interesting to note that when there are no congestion externalities (so $f_2 = 0$), the market equilibrium quota price equals λ, the social value of a quota, and ITQs do exactly what they are intended to do—create incentives to maximize rents to the fishery. When there are congestion externalities ($f_2 < 0$), it is no longer sufficient for the quota price to equal the social value of a quota; fishermen still ignore the congestion cost they impose on other fishermen under ITQs.

We can get some further intuition about this result by considering the case where N is fixed and T is ignored, so that h_i is the season harvest (rather than the rate of harvest per unit time). In this case, the profit function for an individual fisherman is:

$$\pi_i = pf(x_i, x_{-i}) - wx_i - k_i. \tag{16}$$

Here, there is only a single choice: the harvest level of each fisherman, x_i. The social planner would choose x_i to maximize the sum of the profits subject to the constraint in equation (7), rewritten as $Q = \sum_{j=1}^{N} h_j$. The social planner thus chooses the input levels to satisfy:

$$(p - \lambda)f_1 - w + (N - 1)(p - \lambda)f_2 = 0. \tag{17}$$

With ITQs, the profit function in equation (16) becomes:

$$\pi_i = pf(x_i, x_{-i}) - wx_i - mz_i - k_i, \tag{18}$$

with the constraint that the harvest by fisherman i is less than or equal to the quotas purchased by i plus i's initial allocation of quotas:

$$z_i + q_0 \geq f(x_i, x_{-i}). \tag{19}$$

Thus, the ITQ equilibrium is:

$$\lambda_i - m = 0, \text{ and } (p - m)f_1 - w = 0. \tag{20}$$

Therefore, for m chosen such that $m^* = \lambda - (p - \lambda)(N - 1)f_2/f_1$, the pair of externalities is resolved by ITQs. This suggests that if there is *one* variable causing both externalities, a single instrument (ITQs) is sufficient to resolve the externality problem.

However, if we add one even more endogenous variable (say N), ITQs will no longer solve both the common property and congestion externality problems. Suppose, for example, that N is endogenous. Then, the social planner chooses N such that:

$$(p - \lambda)[f + (N - 1)f_2] - wz_i - k_i = 0. \tag{21}$$

Under ITQs, with free entry and exiting, the number of fishermen will satisfy:

$$(p - m)f - wz_i - k_i = 0. \tag{22}$$

Now, plug in the quota price, $m^* = \lambda - (p - \lambda)(N - 1)f_2/f_1$, and the zero-profits condition under ITQs becomes:

$$(p - \lambda)[f + (N - 1)f_2 f/f_1] - wz_i - k_i = 0. \tag{23}$$

Thus, when there are two endogenous variables and two externalities, the single instrument of ITQs is not capable of simultaneously solving both externalities.

From this discussion, one might conclude that the problem with Danielsson's analysis is that he specified his model with only one endogenous variable (the harvest rate). However, this is not what yields his result, as the next section shows.

The Efficiency of ITQs When the Congestion Externality is of the Form $c_i = c(h_i, h_{-j})$

Now, let us assume that the profits to a fisherman are of the form assumed by Danielsson, *i.e.*:[10]

$$\pi_i = T[ph_i - c(h_i, h_{-i})] - k_i, \tag{24}$$

where $c_1 > 0$ and $c_{11} > 0$. The congestion externality occurs because $c_2 > 0$. The social planner's problem is to maximize equation (6) with profits now specified as in equation (24) subject to the constraints of equations (7) and (8). Again, letting λ and

[10] Danielsson uses an infinite time horizon model and makes the curious statement that, "the choice of a model, however is of no importance for the arguments in this paper" (2000, p. 38). I prefer to use the in-season model presented here to talk about ITQs, because no ITQ program allows fishermen to choose the harvest quota, Q, in a particular year. The results of the previous section show clearly that it does matter what the choice of the model is.

τ denote the Lagrange multipliers for these constraints, the necessary conditions include:

$$\begin{aligned} p - \lambda &= c_1 + (N-1)c_2, \\ T[(p-\lambda)h - c - (N-1)c_2 h] &= k, \\ N[(p-\lambda)h - c] &= \tau \geq 0. \end{aligned} \tag{25}$$

In the event that equation (8) is not binding, $\tau = 0$ implies that $-T(N-1)c_2 = k$, which is a contradiction since $c_2 > 0$. Therefore equation (8) is binding, and the equilibrium is characterized by the following:

$$T = \bar{T}, \ \bar{T}Nh = Q, \text{ and } \bar{T}(c_1 h - c) = k \quad \text{Social Optimum.} \tag{26}$$

Notice that the congestion effect ($c_2 > 0$) does not actually play a role in the social planner's solution in equation (26). This is in contrast to my specification in inputs space [see equation (10)], where the congestion effect ($f_2 < 0$) explicitly appears.

Now, consider the ITQ equilibrium. With ITQs, the profit function for an individual fisherman is:

$$\pi_i = T[ph_i - c(h_i, h_{-i})] - mz_i - k_i. \tag{27}$$

The active fisherman chooses h_i, z_i, and T_i to maximize equation (27) subject to equations (8) and (12), where the latter is specified in terms of h_i, rather than in terms of an underlying production function. Again, letting λ_i and τ_i denote the Lagrange multipliers for these constraints, the necessary conditions include:

$$\begin{aligned} \lambda_i &= m, \\ p - m &= c_1, \\ (p-m)h_i - c &= \tau_i \geq 0, \end{aligned} \tag{28}$$

plus the condition that profits equal the return from selling one's quotas:

$$T[(p-m)h_i - c] = k_i. \tag{29}$$

Again, by equation (29), it is clear that the season length constraint, equation (8), is binding for each active fisherman. Thus, the symmetric ITQ equilibrium is given by:

$$T = \bar{T}, \ \bar{T}Nh = Q, \text{ and } \bar{T}(hc_1 - c) = k \quad \text{ITQ Equilibrium.} \tag{30}$$

This demonstrates the point made by Danielsson that ITQs are efficient in the presence of congestion externalities when the congestion externalities are defined in terms of the cost function $c(h_i, h_{-i})$, where $c_1 > 0$ and $c_2 > 0$ is assumed. It also shows that Danielsson's point does not depend upon the fact that there is only one endogenous variable (the harvest level) in his model.

It might be thought that one can simply solve the input model of congestions in the previous section for the x_i as functions of the harvest levels, *e.g.*, $x_i = g(h_i, h_{-i})$, and substitute these into the objective function to obtain a cost function with the properties that $c_1 > 0$ and $c_2 > 0$. However, while it is apparently possible to solve for the inputs in terms of the outputs, it does *not* follow that the derived cost function would have the properties assumed by Danielsson. If this were true, then the qualitative properties of the models would be identical. I have shown here that the qualitative properties are not the same. Therefore, the duality theorems for an individual price-taking firm do not aggregate to an entire industry.

Note also that the equilibrium quota price is rather curious: $m = \lambda + (N - 1)c_2 > \lambda$, since $c_2 > 0$. This means that the equilibrium price no longer reflects the social value of an additional harvest quota (recall that λ is equal to the value of another unit of quota, already taking account of the congestion externality). This is a strange result, and it goes without explanation or discussion by Danielsson.

The Efficiency of ITQs When the Congestion Externality is of the Form $\hat{c}(h_i, N)$

To further emphasize my point that it is inputs that matter for congestion externalities, consider a cost function that has been used by Smith (1968, 1969), Brown (1974), and Karpoff (1987). Assume that profits to a fisherman are of the following form (where $\hat{c}_2 > 0$ is the congestion externality):

$$\pi_i = T\left[ph_i - \hat{c}(h_i, N) - k_i\right]. \tag{31}$$

The social planner's problem is to maximize equation (6) with profits now specified as in equation (31) subject to the constraints in equations (7) and (8). Again, letting λ and τ denote the Lagrange multipliers for these constraints, the necessary conditions include:

$$\begin{gathered} p - \lambda = \hat{c}_1 \\ T\left[(p - \lambda)h - \hat{c} - N\hat{c}_2\right] = k \\ N\left[(p - \lambda)h - \hat{c}\right] = \tau \geq 0. \end{gathered} \tag{32}$$

As in the previous model, if the season length constraint, equation (8), is not binding, it implies $\tau = 0$, but this results in $-TN\hat{c}_2 = k$, which is a contradiction. Thus, the social planner's solution includes:

$$T = \bar{T},\ TNf = Q, \text{ and } T\left[h\hat{c}_1 - \hat{c} - N\hat{c}_2\right] = k \text{ Social Optimum.} \tag{33}$$

Under ITQs, fishermen choose h_i, z_i, and T_i to maximize:

$$\pi_i = T\left[ph_i - \hat{c}(h_i, N)\right] - mz_i - k_i. \tag{34}$$

Subject to the constraints in equations (8) and (12), with the latter appropriately specified with h_i instead of the production function f, the necessary conditions include:

$$\begin{gathered} \lambda_i = m, \\ p - m = \hat{c}_1 \\ (p - m)h_i - \hat{c} = \tau \geq 0 \end{gathered} \tag{35}$$

plus the condition that profits equal the return from selling one's quotas:

$$T\left[(p - m)h_i - \hat{c}\right] = k_i. \tag{36}$$

These may be combined to show that the symmetric ITQ equilibrium includes the following:

$$T = \bar{T}, \ \bar{T}Nh = Q, \text{ and } \bar{T}\left[\hat{c}_1 h - \hat{c}\right] = k, \quad \text{ITQ Equilibrium.} \tag{37}$$

Again, the ITQ equilibrium and the social planner's conditions do not match. It is clear from equation (37) that the difference is simply that the individual fisherman ignores the congestion externality [the $N\hat{c}_2$ term in the third expression of equation (33)]. Thus, when the cost function is specified in a manner that is consistent with the congestion externality as exhibited in equation (1), the result is that ITQs do not maximize social welfare.

Pecuniary Externalities

I argue that Danielsson has specified his profit function such that it is indistinguishable from a pecuniary externality. To see this, suppose that instead of a congestion externality in the form of equation (24), it is assumed that price depends upon the aggregate harvest rate per unit time; *i.e.*, $p = p(\sum_{j=1}^{N} h_j)$, where $p' < 0$, and that an individual fisherman's costs depend only upon that fisherman's own output; *i.e.*, $c_i = \bar{c}(h_i)$, with $\bar{c}' > 0$ and $\bar{c}'' > 0$. Thus, there is no congestion externality as specified by Danielsson, but there is a pecuniary externality. The profit of an individual fisherman is thus:

$$\pi_i = T\left[p\left(\sum_{j=1}^{N} h_j\right)h_i - \bar{c}(h_i)\right] - k_i. \tag{38}$$

The social planner's problem is to maximize:

$$V = T\left(\int_0^{\sum_{j=1}^{N} h_j} p(s)ds - \sum_j \bar{c}(h_j)\right) - \sum_{j=1}^{N} k_j \tag{39}$$

subject to equations (7) and (8). The maximized values of N, h, T, and λ satisfy the following necessary conditions:

$$\begin{aligned} p(Nh) - \lambda &= \bar{c}' \\ T\{[p(Nh) - \lambda]h - \bar{c}\} &= k \\ N\{[p(Nh) - \lambda]h - \bar{c}\} &= \tau \geq 0. \end{aligned} \tag{40}$$

In addition, both equations (7) and (8) hold with equality. Thus, the social optimum includes:

$$T = \bar{T}, \ \bar{T}Nh = Q, \text{ and } \bar{T}\left[\bar{c}'h - \bar{c}\right] = k, \quad \text{Social Optimum.} \tag{41}$$

Now, consider the ITQ equilibrium in which each fisherman acts as a price taker in both the quota and output markets, but chooses his own season length. In this case, profits are:

$$\bar{\pi}_i = T_i\left[p(\Sigma_j h_j)h_i - \bar{c}(h_i)\right] - k_i - m(T_i h_i - q_0). \tag{42}$$

The necessary conditions for an active fisherman (one who does not sell his quotas and retire) include:

$$\begin{aligned} &p(Nh) - m - \bar{c}' = 0 \\ &N\{[p(Nh) - m]h - \bar{c}\} = \tau \geq 0 \quad \text{ITQ Equilibrium} \\ &T\{[p(Nh) - m]h - \bar{c}\} = k. \end{aligned} \tag{43}$$

These, in turn, are identical to equation (40) for $m = \lambda$.

Thus, with a pecuniary externality but no congestion externality, ITQs solve the common property problem. So what? In equation (24), where a congestion externality of the form Danielsson uses has been specified, and equation (42), where there is no congestion externality but there is a pecuniary externality (and where $z_i = Th_i - q_0$ has been substituted out), we see that the price-taking firm's profits have the properties that:

$$\frac{\partial \pi_i}{\partial h_{-i}} = -Tc_2(h_i, h_{-i}) < 0 \quad \text{and} \quad \frac{\partial \bar{\pi}_i}{\partial h_{-i}} = Tp'(Nh)h_i < 0. \tag{44}$$

Thus, Danielsson's result is a direct result of the fact that his specification of a profit function with a congestion externality is indistinguishable in first differences from that of a profit function with a pecuniary externality. It is, therefore, no surprise that he finds that a single instrument, such as ITQs, is sufficient to overcome this externality.

Conclusion

There are two ways in which a congestion externality is resolved when ITQs are introduced in a fishery. One is when there is only a single endogenous variable causing both the common property and congestion externalities. Here, a single instrument is sufficient. The other is when the congestion externality is expressed in the form of a cost function with $c_i = c(h_i, h_{-i})$, as in Danielsson. Danielsson does not review the literature on congestion externalities to see how they have been modeled by other authors—myself excepted. His externality is certainly not the congestion externality that has been modeled previously in either the fisheries literature or the road congestion literature. Nor does Danielsson attempt to justify his assumptions or to draw out the economic nature of the difference between his model and the model considered by others and myself. Indeed, he does not show the underlying production relationship that his cost function implies.

Danielsson claims that the congestion externality is due to outputs—so fisherman *i*'s costs rise as the output of other fishermen increases. The externality due to outputs with price taking firms is a pecuniary externality, not a congestion externality. True, profits to fishermen *i* decrease as other fishermen's aggregate output increases when there exists a pecuniary externality, but this is not an externality that economists think requires fixing. Indeed, it is difficult to conceptualize the economic nature of the externality in Danielsson's model. Congestion on a roadway is caused by the number (or types) of cars using it—an input measure—not by the speed of the cars—the output measure. In Danielsson's specification, it is more costly to drive fast when other drivers are going fast. It seems much more likely that it is more costly to drive fast when other drivers are going slowly. Similarly, congestion in a fishery is due to inputs, not outputs. A fisherman catches fewer fish because he has to elbow his way through all of the other fishermen to get a chance to fish—not because the other fishermen are catching all the fish.

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